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Thermal Time - Variability in Eastern Region, ADAS

by J Cochrane

Summary

Statistics of thermal time (accumulated temperatures above 0°C) are presented for 4 stations in Eastern Region, ADAS. The possibilities of using thermal time estimates, based on available meteorological data, to assist in advice on application of fertilizers and herbicides to winter cereals is examined.

Introduction

Hough (Ag Mem 1002) has described the relationships found between thermal time and cereal leaf development in Yorkshire between 1980 and 1983. Several studies are currently being made in parts of the Eastern Region to validate this approach for advice on fertilizer and herbicide applications according to growth stage as indicated by thermal time since drilling.

For advisory purposes, it is felt useful to be able to relate the value of development of a given crop under study to the average (or expected) rate and to be able to predict when the next critical development stage will be reached.

Normal temperature forecasts (for up to 3 days ahead) are inadequate for this purpose and a climatological approach to the problem is examined in this paper.

Data and Methods

Hough (Op cit) following Monteith, defined thermal time as the accumulation of positive mean daily temperatures from drilling. In this paper accumulated temperatures above 0°C (calculated from daily maximum and minimum temperatures) are used.

Accumulated temperatures for ten seasons, September 1973 to June 1983 have been calculated for 4 stations in the Eastern Region:-

Station	N.G.R.	Altitude
Broom's Barn	TL 753 657	75 m
Coltishall	TG 262 229	17 m
Honington	TL 887 749	49 m
Marham	TF 726 094	23 m

The daily data were summed in periods of 1st to 10th, 11th to 20th and 21st to 28th, 29th, 30th or 31st for each month. Individual "10-day" totals and cumulative totals from 1st September were ranked in ascending order. Lower quart, median and upper quart values were estimated by linear interpolation between ranks 2 and 3, 5 and 6 and 7 and 8 respectively. These values, together with the highest and lowest in 10 years are shown in Tables 1 to 8.

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Discussion

Despite differences in altitude, coastal influence and soil type, differences in accumulated temperature between the 4 stations are small. Figure 1 shows the variation of the difference between median "10-day" totals at Broom's Barn, Coltishall and Marham, from Honington through the season. Honington, Broom's Barn and Coltishall are very similar while Marham is about 1°C per 10 days colder.

Differences in variability are shown in Figure 2 in terms of interquartile ranges compared to Honington. Mean interquartile range at Honington is 33.7 with standard deviation of 8.9; only Coltishall shows a significant increase in variability over the other 3 stations.

There is a suggestion in the data that Broom's Barn, the highest of the 4 stations may be anomalously warm - possibly due, in part at least, to the warming and sheltering effect of the office buildings to the north of the enclosure.

The general trend of "thermal time" from September 1st is shown for Honington in Figure 3. It is a useful quality of the data that while the interquartile range does increase during the winter period, the variability is least when the rate of increase is greater. Hence the predictive uncertainty is greater when rate of development is slow and more time is available to adjust errors in extrapolation.

Advisory Use

Median cumulative curves to 1000° days for drilling dates from 1st September, by 10-day intervals, to 10th November are shown in Figure 4. Progress for any crop in the current season may be compared with these curves while the initial observations to determine the thermal time per leaf are carried out. Figure 5 allows extrapolation to be made in terms of likely increase per 10 days, using data from the most appropriate station.

Note that some smoothing was done before Figures 4 and 5 were drawn:-

a) End of month values were adjusted to 10-day accumulations, eg. 21st to 31st October totals were reduced by 9%.

b) Median values were smoothed by replacing the Nth value by -

$$1/4\ ((N-1)\text{th} + 2\ (\text{Nth}) + (N+1)\text{th})$$

The data making up Figure 5 can be inverted to give statistics of "number of days per leaf" for any given leaf thermal time interval. Figure 6 shows median and quartile values for Honington assuming a 110° day interval between leaves. Estimates for other thermal time intervals may be obtained by adjusting the values proportionately, eg. for a 95° day interval between leaves the value obtained from Figure 6 should be reduced to $95\ N/110 = 0.86\ N$ where N is the number of days per leaf for a 110° day interval.

Weather forecasts should be used to assess whether temperatures are likely to be average, above or below average during the next week.

Extension

To complete this initial analysis, from computer-produced daily values of accumulated temperatures, involved a considerable amount of hand processing which was both tedious and time consuming.

A possible short-cut approach, using the graphical Thom's Method described by Harvey in Ag Mem 527, has been tested for the 4 stations used in this paper. Table 9 shows average monthly totals (rounded to 5° days per month) found by this method compared with the median values already evaluated.

These monthly data will give acceptable estimates of the median curves shown in Figures 3 to 6, as can be seen from the plot of "°C days per 10 days" inferred from the monthly averages for Honington plotted for mid-month in Figure 5. While this approach does not give year to year variability, use of the interquartile range already found should be adequate for advisory purposes.

If it is felt that greater accuracy and detail is necessary, then a computer program to perform the complete analysis could be written to run on data held in the Meteorological Office Cosmos computing system.

Any comments on this paper should be sent to the author.

Agrometeorological Department
ADAS, Cambridge

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References

Hough, M. N. (1983). Leaf appearance and thermal time for winter cereals. Ag. Mem. 1002.

Harvey, L. D. J. (1973). Simple computation of degree days above or below any base. Ag. Mem. 527.

Table 1

Values of Cumulative Accumulated Temperatures above 0°C 1973-1983

at Broom's Barn

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	136	141	159	173	186
11-20	262	283	305	329	334
21-30	389	432	434	462	464
OCT 1-10	463	537	565	577	580
11-20	537	633	657	677	699
21-31	609	733	764	793	804
NOV 1-10	678	801	831	899	913
11-20	743	871	889	965	1019
21-30	807	908	954	1009	1067
DEC 1-10	895	953	980	1073	1111
11-20	950	978	1014	1121	1159
21-31	999	1032	1079	1168	1207
JAN 1-10	1033	1075	1127	1222	1228
11-20	1057	1117	1175	1237	1283
21-31	1107	1161	1236	1262	1349
FEB 1-10	1161	1205	1290	1297	1369
11-20	1211	1243	1309	1354	1376
21-28/9	1243	1263	1347	1393	1403
MAR 1-10	1303	1335	1415	1445	1466
11-20	1363	1388	1467	1491	1549
21-31	1422	1447	1533	1567	1602
APR 1-10	1480	1513	1588	1654	1670
11-20	1575	1585	1667	1735	1742
21-30	1658	1679	1758	1806	1813
MAY 1-10	1720	1763	1861	1891	1914
11-20	1859	1881	1963	2016	2027
21-31	1996	2025	2103	2142	2154
JUN 1-10	2111	2161	2261	2285	2294
11-20	2231	2309	2400	2428	2447
21-30	2367	2453	2531	2575	2641

Table 2

Values of Cumulative Accumulated Temperatures above 0°C 1973-1983

at Coltishall

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	134	143	153	165	179
11-20	258	281	303	314	327
21-30	378	417	431	448	459
OCT 1-10	473	543	535	569	572
11-20	548	640	649	665	687
21-31	635	730	753	787	797
NOV 1-10	703	803	833	880	900
11-20	766	880	897	951	995
21-30	825	925	959	1003	1053
DEC 1-10	914	970	994	1069	1103
11-20	968	995	1038	1131	1152
21-31	1017	1051	1109	1181	1210
JAN 1-10	1051	1087	1167	1207	1251
11-20	1075	1130	1203	1243	1280
21-31	1131	1189	1254	1290	1325
FEB 1-10	1183	1229	1293	1332	1348
11-20	1220	1257	1343	1355	1369
21-28/9	1241	1286	1384	1395	1413
MAR 1-10	1299	1357	1423	1457	1467
11-20	1357	1417	1489	1523	1533
21-31	1424	1471	1563	1588	1607
APR 1-10	1497	1529	1620	1663	1676
11-20	1569	1607	1701	1729	1758
21-30	1654	1696	1792	1805	1815
MAY 1-10	1730	1773	1883	1895	1909
11-20	1858	1892	1991	2009	2034
21-31	2010	2026	2101	2137	2171
JUN 1-10	2152	2169	2253	2293	2318
11-20	2277	2302	2385	2453	2460
21-30	2416	2445	2522	2581	2654

Table

Values of Cumulative Accumulated Temperatures above 0°C 1973-1983

at Honington

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	135	141	157	168	186
11-20	263	273	305	327	337
21-30	377	416	430	459	467
OCT 1-10	455	535	559	576	583
11-20	530	634	649	677	693
21-31	604	729	761	786	794
NOV 1-10	672	797	829	894	900
11-20	738	872	885	963	993
21-30	802	904	949	1007	1042
DEC 1-10	893	947	976	1069	1090
11-20	948	979	1012	1115	1135
21-31	1014	1031	1071	1166	1185
JAN 1-10	1046	1071	1125	1207	1233
11-20	1058	1113	1182	1223	1288
21-31	1110	1167	1226	1261	1355
FEB 1-10	1167	1210	1284	1295	1376
11-20	1219	1235	1303	1347	1385
21-28/9	1248	1257	1345	1385	1414
MAR 1-10	1315	1325	1398	1441	1476
11-20	1357	1387	1465	1485	1558
21-31	1407	1452	1533	1565	1612
APR 1-10	1464	1521	1585	1651	1669
11-20	1562	1588	1667	1727	1739
21-30	1639	1683	1761	1801	1823
MAY 1-10	1699	1768	1863	1883	1923
11-20	1844	1883	1965	2013	2030
21-31	1979	2028	2096	2139	2150
JUN 1-10	2121	2161	2256	2285	2297
11-20	2245	2309	2399	2431	2446
21-30	2384	2454	2531	2579	2642

Table 4

Values of Cumulative Accumulated Temperature above 0°C 1973-1983

at Marham

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	133	139	154	165	177
11-20	259	275	297	319	325
21-30	373	416	423	448	452
OCT 1-10	451	529	548	564	566
11-20	525	619	645	660	679
21-31	605	713	742	776	786
NOV 1-10	673	779	813	877	884
11-20	732	851	867	943	974
21-30	791	886	935	983	1024
DEC 1-10	879	929	961	1053	1029
11-20	933	960	989	1090	1115
21-31	974	1015	1047	1135	1167
JAN 1-10	1005	1045	1103	1173	1204
11-20	1030	1085	1152	1204	1229
21-31	1085	1137	1193	1238	1290
FEB 1-10	1144	1177	1237	1270	1309
11-20	1188	1202	1279	1307	1319
21-28/9	1213	1231	1325	1347	1349
MAR 1-10	1271	1299	1361	1406	1410
11-20	1320	1360	1421	1459	1489
21-31	1374	1420	1497	1533	1551
APR 1-10	1438	1489	1565	1609	1617
11-20	1536	1559	1655	1682	1695
21-30	1613	1655	1733	1750	1763
MAY 1-10	1675	1741	1839	1845	1850
11-20	1818	1859	1949	1971	1979
21-31	1950	2001	2077	2105	2111
JUN 1-10	2095	2121	2220	2261	2266
11-20	2217	2271	2363	2409	2426
21-30	2354	2413	2503	2534	2644

Table 5

Values of Accumulated Temperatures above 0°C 1973-1983

at Broom's Barn

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	136	141	159	173	186
11-20	127	129	148	157	173
21-30	96	111	138	145	161
OCT 1-10	75	108	116	131	147
11-20	73	73	93	118	128
21-31	72	84	105	123	136
NOV 1-10	33	70	81	107	112
11-20	36	54	62	79	106
21-30	29	35	56	69	75
DEC 1-10	24	27	45	68	100
11-20	3	17	45	57	71
21-31	14	27	56	71	98
JAN 1-10	13	27	41	70	75
11-20	11	11	25	67	73
21-31	5	28	55	67	70
FEB 1-10	17	21	47	59	65
11-20	3	6	33	55	64
21-28/9	9	21	37	49	75
MAR 1-10	33	43	61	69	84
11-20	32	37	59	75	83
21-31	42	49	67	80	104
APR 1-10	33	50	73	83	105
11-20	48	66	79	99	111
21-30	54	67	79	96	113
MAY 1-10	62	80	93	103	130
11-20	94	98	122	133	146
21-31	103	118	133	139	156
JUN 1-10	115	125	148	159	188
11-20	120	128	139	153	161
21-30	122	127	144	148	218

Table 6

Values of Accumulated Temperatures above 0°C 1973-1983

at Coltishall

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	134	143	153	165	179
11-20	124	137	145	157	160
21-30	97	115	135	144	152
OCT 1-10	95	107	119	131	146
11-20	75	77	97	115	117
21-31	82	85	104	119	133
NOV 1-10	50	67	83	103	115
11-20	42	59	67	79	94
21-30	28	48	58	75	78
DEC 1-10	28	34	48	72	96
11-20	6	27	44	57	68
21-31	19	33	56	75	96
JAN 1-10	14	31	39	72	75
11-20	15	18	29	67	73
21-31	8	33	53	67	68
FEB 1-10	22	23	45	53	62
11-20	5	10	35	55	62
21-28/9	11	20	36	50	73
MAR 1-10	31	44	62	68	84
11-20	38	40	59	75	82
21-31	46	51	65	77	103
APR 1-10	39	53	68	80	90
11-20	47	67	77	94	99
21-30	57	69	77	94	102
MAY 1-10	61	79	93	97	117
11-20	87	98	119	125	144
21-31	103	117	131	137	155
JUN 1-10	114	123	150	158	172
11-20	123	130	140	153	164
21-30	124	128	140	145	201

Table 7

Values of Accumulated Temperatures above 0°C 1973-1983

at Honington

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	135	141	157	168	186
11-20	125	129	144	156	180
21-30	98	112	138	143	160
OCT 1-10	78	107	119	130	146
11-20	73	74	94	116	123
21-31	75	79	103	122	136
NOV 1-10	36	69	79	105	113
11-20	37	53	63	78	95
21-30	26	36	56	70	73
DEC 1-10	25	27	44	71	97
11-20	2	18	44	56	67
21-31	15	27	56	71	97
JAN 1-10	13	26	41	71	77
11-20	11	12	23	69	73
21-31	5	29	55	67	71
FEB 1-10	18	21	47	59	64
11-20	5	8	36	56	66
21-28/9	8	21	33	49	72
MAR 1-10	31	43	61	69	85
11-20	35	39	59	75	82
21-31	45	51	66	82	104
APR 1-10	37	51	66	85	105
11-20	46	67	77	98	110
21-30	53	67	76	96	112
MAY 1-10	60	79	93	103	131
11-20	94	98	123	132	145
21-31	104	120	134	139	156
JUN 1-10	115	127	150	162	187
11-20	124	131	142	158	164
21-30	124	128	144	149	217

Table 8

Values of Accumulated Temperatures above 0°C 1973-1983

at Marham

Date	Lowest	Lower Quart	Median	Upper Quart	Highest
SEP 1-10	133	139	154	165	177
11-20	126	129	143	153	165
21-30	95	112	133	144	161
OCT 1-10	78	102	115	127	149
11-20	72	73	95	114	126
21-31	77	78	102	115	127
NOV 1-10	44	66	76	98	114
11-20	35	54	59	76	90
21-30	26	36	55	69	72
DEC 1-10	23	27	43	70	93
11-20	3	20	43	53	64
21-31	15	27	52	70	94
JAN 1-10	11	26	37	69	69
11-20	11	13	24	63	74
21-31	5	28	51	63	65
FEB 1-10	16	20	44	56	64
11-20	4	8	34	54	64
21-28/9	9	21	36	49	73
MAR 1-10	36	44	59	69	81
11-20	35	40	56	74	80
21-31	46	51	67	81	103
APR 1-10	38	53	67	86	102
11-20	47	66	80	100	112
21-30	54	69	77	95	99
MAY 1-10	62	82	93	101	126
11-20	94	96	123	137	143
21-31	103	120	134	143	160
JUN 1-10	118	125	145	162	188
11-20	119	130	143	156	160
21-30	123	127	141	148	218

Table 9

Monthly total of accumulated temperatures above 0°C

A) Median value 1973-1983 and

B) Average value 1951-1980 using Thom's Method.

	Honington		Marham	
	A	B	A	B
SEP	439	425	430	420
OCT	316	330	312	330
NOV	198	185	190	180
DEC	144	140	138	140
JAN	119	120	112	110
FEB	116	115	114	105
MAR	186	170	182	170
APR	219	225	224	230
MAY	350	355	350	355
JUN	446	435	429	430
TOTAL	2531	2500	2481	2470

	Broom's Barn		Coltishall	
	A	B	A	B
SEP	435	420	433	420
OCT	314	330	320	335
NOV	199	185	208	195
DEC	146	140	148	150
JAN	121	120	121	115
FEB	117	115	116	105
MAR	187	170	186	170
APR	231	225	222	225
MAY	348	350	343	345
JUN	431	430	430	425
TOTAL	2529	2485	2527	2485

Median "10-day" totals - Differences from Honington

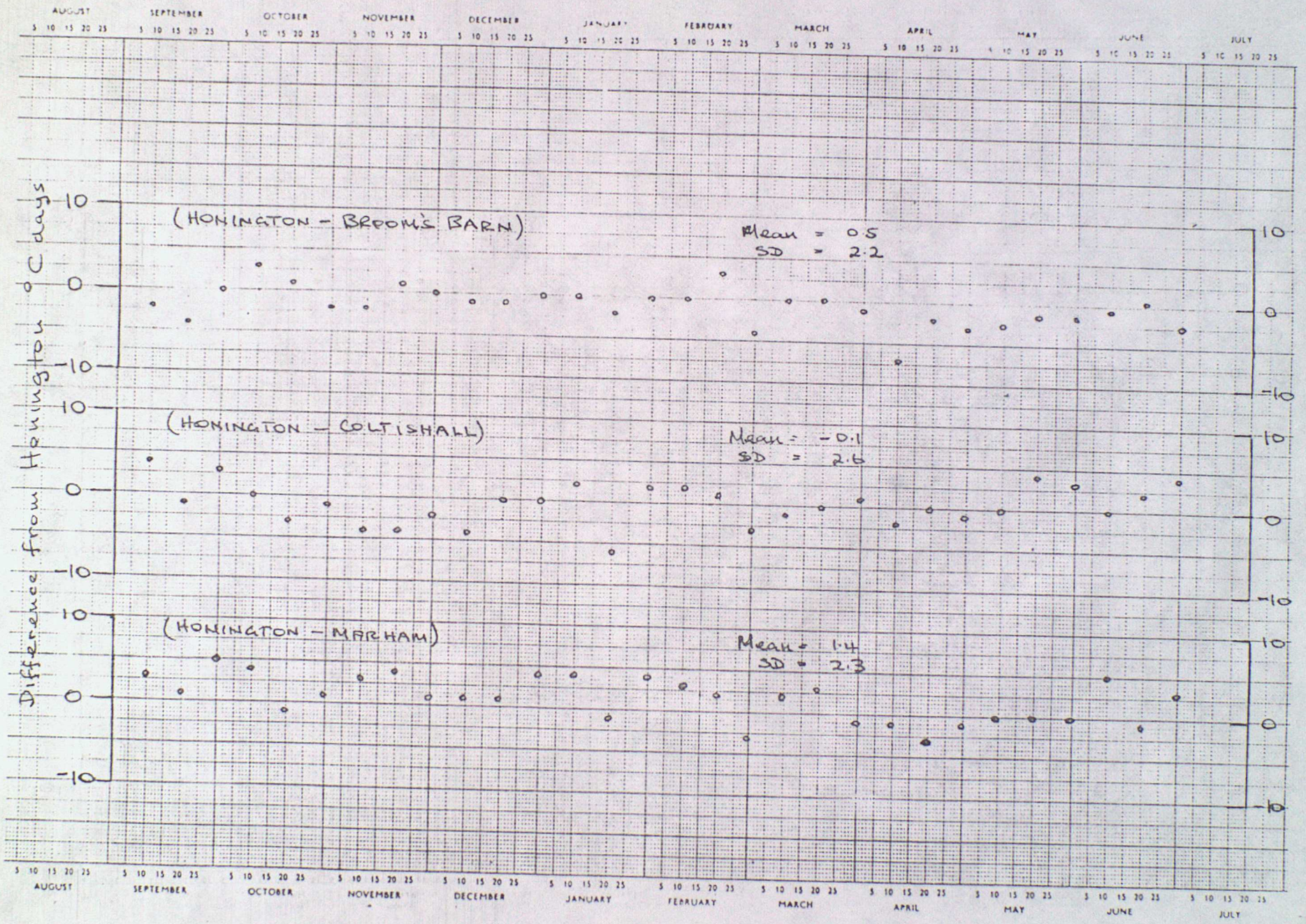


Figure 1

"10-day" totals: inter quartile range - difference from Honington

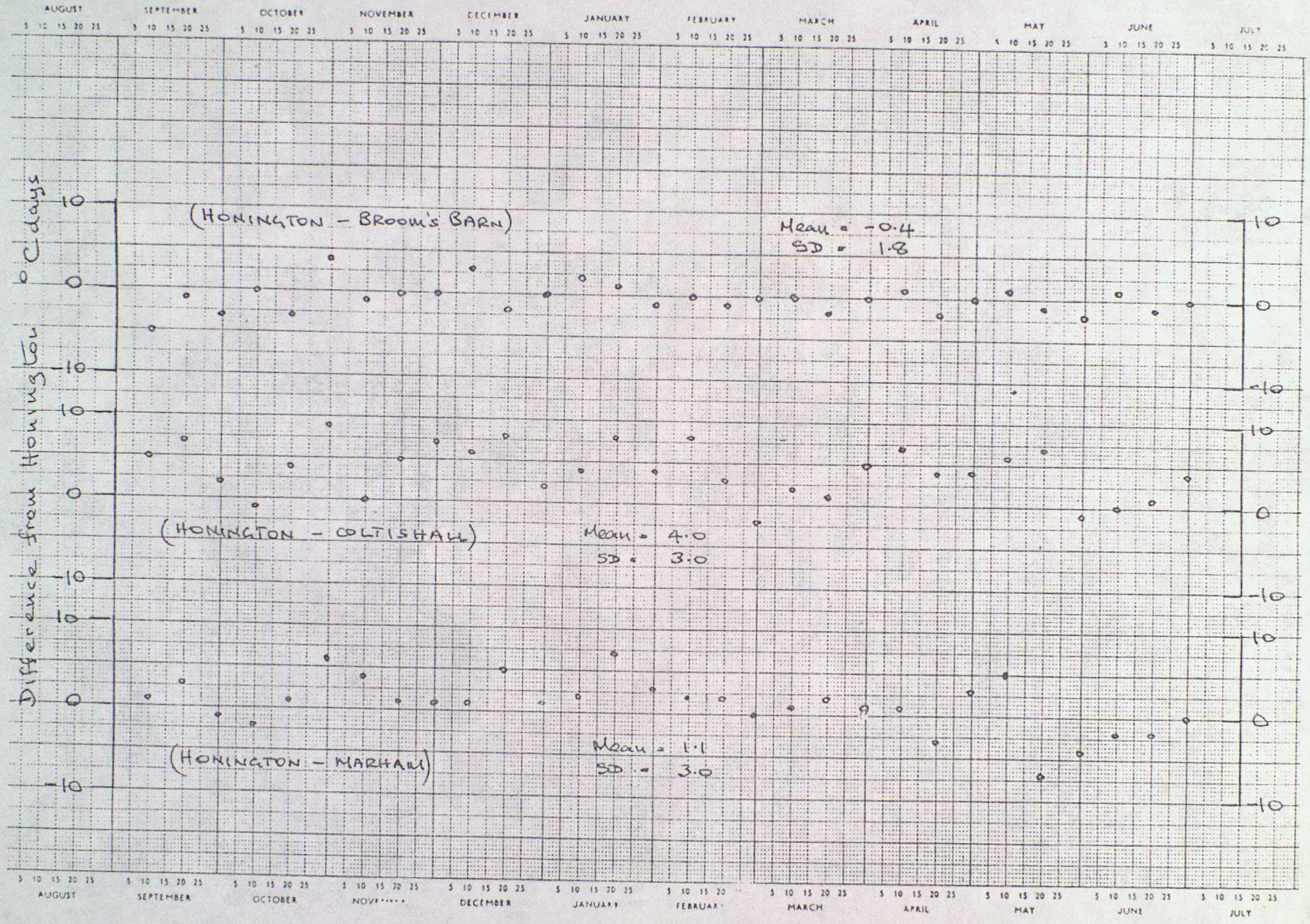


Figure 2

Cumulative accumulated temperature above 0°C from 1 September

Median and inter quartile range

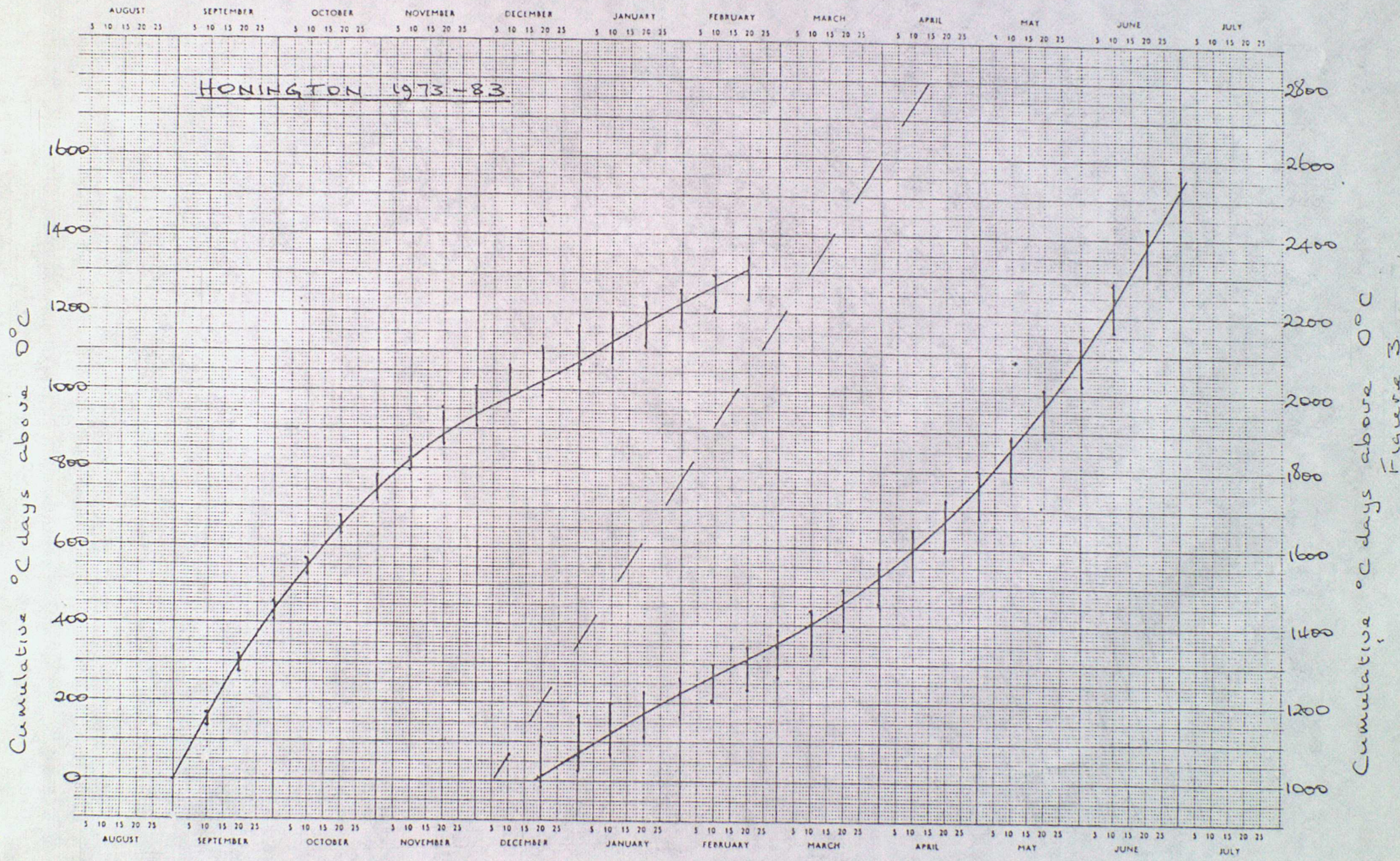
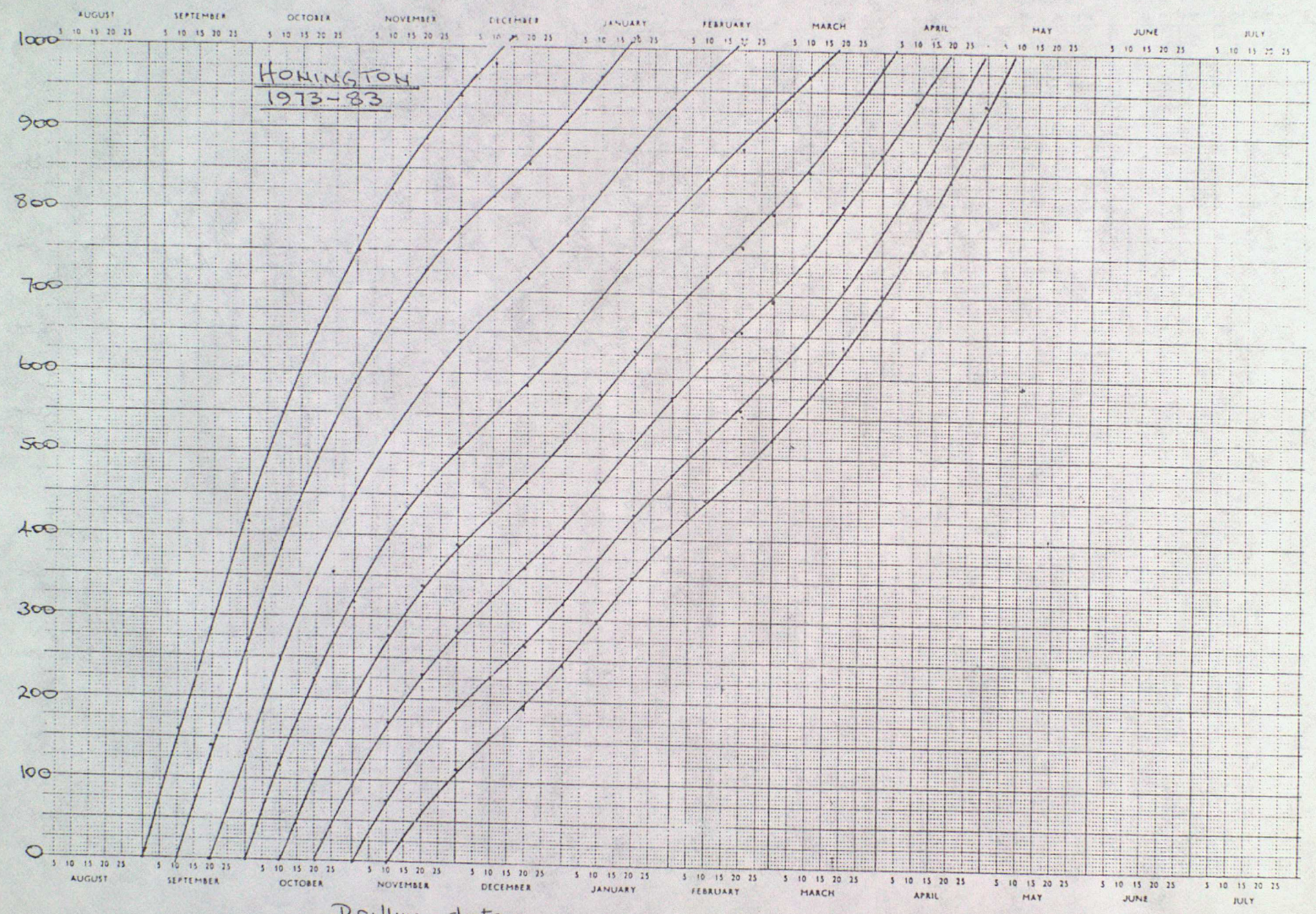


Figure 3

Median cumulative °C days above 0°C to 1000° days



Cumulative °C days above 0°C

Drilling date

Figure 4

Median, upper and lower quart values of accumulated temperature

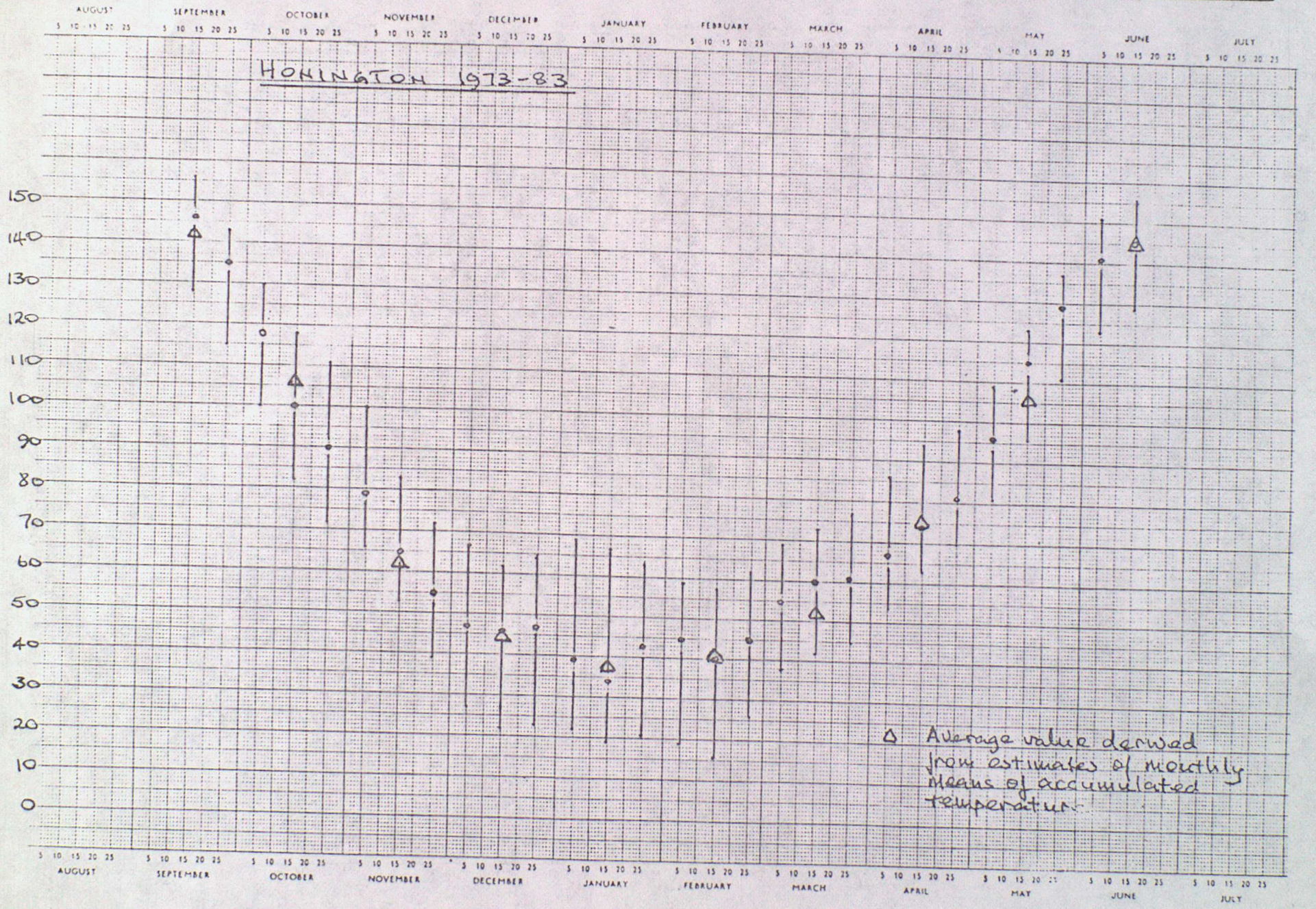


Figure 5

Median, upper and lower quart values of no. of days per leaf

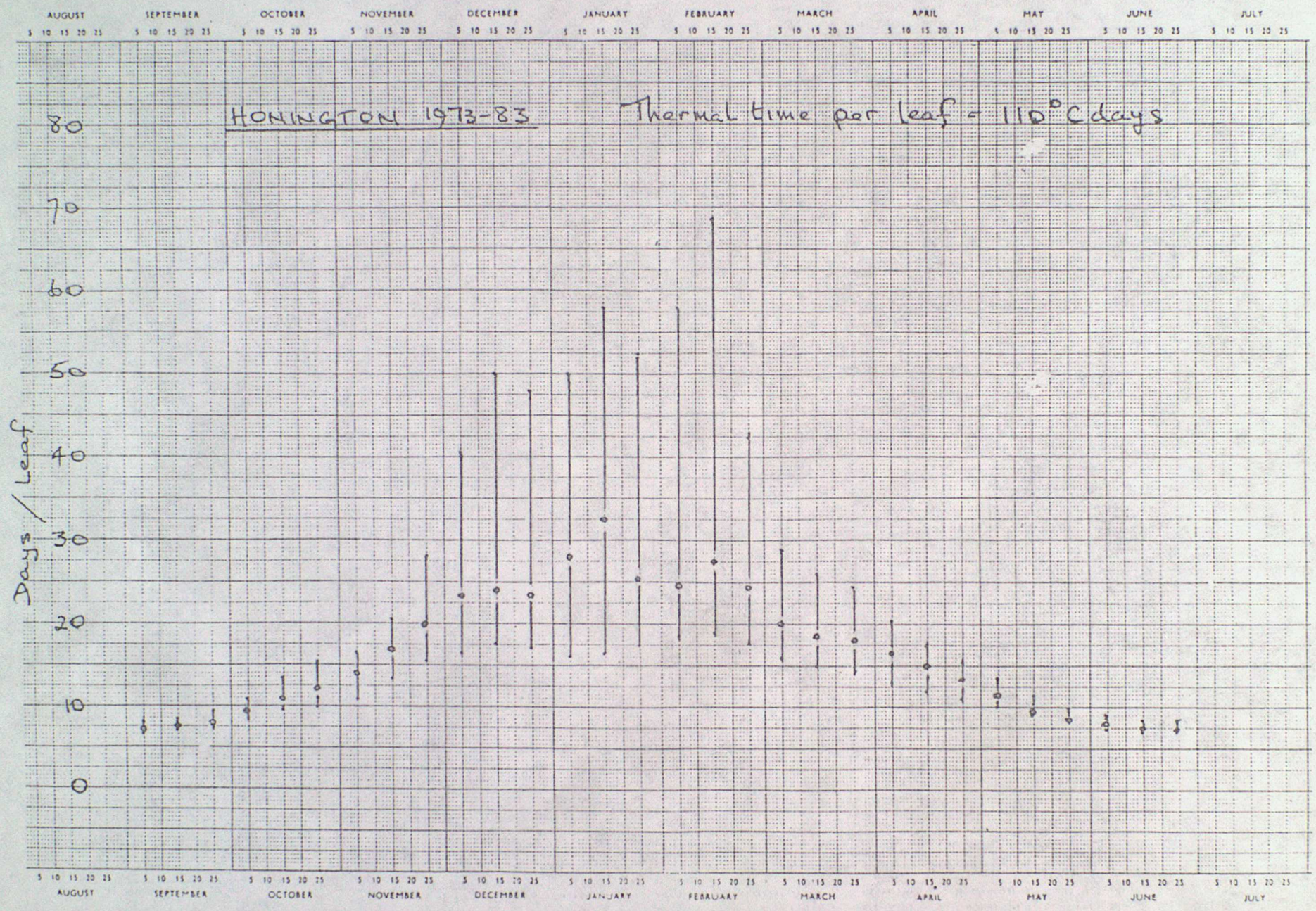


Figure 6